Cold Crack Susceptibility studies on High Strength Low Alloy Steel 950A using Tekken Test

V.Manivelmuralidaran[1,a], M.sakthivel[2,b], M.Balaji[3,c]
[1]Assistant Professor, Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore, India,
[2]Professor, Department of Mechanical Engineering, Info Institute of Engineering, Coimbatore, India ,
[3]Associate Professor, Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore, India,
[a]amritamani@gmail.com, [b]sakthivelm1962@gmail.com,
[c]balaji.m.mec@kct.ac.in

ABSTRACT

In This research article deals with the study of cold cracking susceptibility of High Strength Low Alloy Steel (HSLA) 950A using Gas Metal Arc Welding process (GMAW). The cold cracking is a general problem while welding HSLA steels. It thus becomes mandatory to have a novel method of welding to minimize the effects of cold cracking. The cold cracking tendency of the material is determined using the Y groove Tekken test and the test is carried out with DIN EN ISO 17642–2 standard. The welding of the base metal has been carried out using the low hydrogen electrode ER 70SD2. The test procedure is followed under self-restraint condition for determining cold cracking susceptibility of weld metal. Micro structural constituent of the weld metal plays an important role in determining the cold crack susceptibility of the weld metal. Hence an attempt has been made to impart the microstructure having high resistance to cold cracking. It has been observed that Acicular ferrite microstructure in the weld metal increases the cold cracking resistance of the welded joint. In the present study, the effect of preheating temperature on cold crack susceptibility analyzed by varying the preheating temperature 100ºC, 150ºC and acicular ferrite microstructure observed in the microstructure analysis of the welded specimen. The effect of microstructure on cold cracking has also been established. But due to very limited range of temperature, the effect of preheating temperature on cold crack susceptibility was inconclusive. But the formation of acicular ferrite microstructure will have greater influence on cold crack susceptibility. In future, effects of Nickel, Manganese and other alloying elements of the filler material in increasing cold cracking resistance can also be studied for far reaching prospects of the research.

Indexing terms/Keywords

High Strength Low Alloy steel, Cold cracking, Gas Metal Arc Welding, Tekken test, Acicular ferrite

Academic Discipline And Sub-Disciplines

Mechanical Egineering

SUBJECT CLASSIFICATION

Welding

TYPE (METHOD/APPROACH)

Experimental analysis

INTRODUCTION

HSLA steels are used widely for construction of large scale welded structures. HSLA steel is a type of alloy steel that provides better mechanical properties[1]. The prime advantages of these types of steels are combination of high strength and toughness. HSLA steels vary from other steels, they are specific mechanical properties intended for their service[2]. They have a carbon content between 0.05-0.25% to retain formability and weldability. The cold crack susceptibility tests have been extensively tried and proven cold cracking test procedures are available [3]. The cold cracking test procedures and diverse investigation methods may also serve to determine hot crack formation during welding [4]. This is frequently dependent solely on the achievable stiffness conditions and external loads and also dependent on the associated thermo mechanical effects during welding and cooling [5]. Depending on their execution, cold cracking tests provide qualitative results (crack/no crack) or quantitative results for the investigated material/filler material combinations [6].

The cold cracking test procedures can be classified according to the type of loading into self-restraint and externally loaded tests [7]. Self-restraint cold cracking tests imply a structural load of which the level depends on the constructional stiffness conditions of the specimen as well as on phase transformation[3,8]. The objective of study is to determine the effect of preheating temperatures on cold crack susceptibility of HSLA steel. Along with other factors, cooling rate plays an important role in determining final weld microstructure [9,10]. Thus, the preheating temperature was selected from the literature and fixed as 100ºC and 150ºC. Microstructural constituent plays an important role in deciding the weld metal toughness. [11,16-18]. Mechanical properties of the welded joints are depend upon thejoint characteristics and thereby improvement of mechanical property is essential to have sound welds.

SPECIMEN PREPARATION FOR TESTING

The test material taken for the study is HSLA steel of SAE Grade 950A with thickness 12mm and dimensions of 200mmX150mm. The chemical composition for the material is shown in Table 1.

Table.1. Chemical composition of HSLA steel 950A(Base Metal)

C	Mn	S	P	Si	Fe
0.15%	1.30 %	0.05%	0.04%	0.90%	Remaining

The Filler material selected for the study is ER70S-D2 which is found suitable for welding HSLA steels. This filler electrode has been preferred because of low hydrogen content [12-13]. The electrode was dehydrated prior to welding and its chemical composition and mechanical properties are shown in Table 2 and Table 3 respectively.

Table 2. Chemical composition of filler metal ER70S-D2

Composition	Percentage
Carbon	0.07%
Magnesium	0.90 % - 1.40%
Silicon	0.40-0.70%
Phosperous	0.025%
Sulfur	0.035%
Nickel	0.15%
Chromium	0.15%
Molybdenum	0.15%
Vanadium	0.03%
Aluminum	0.05-0.15%
Zirconium	0.02-0.12%
Tin	0.05-0.15%
Copper	0.50%

Table.3. Mechanical Properties of Filler metal ER70S-D2

Tensile Strength	497 N/mm^2
Yield Strength	414 N/mm^2
Elongation in 2”	22% Min.

The filler metal can yield better properties while using Carbon dioxide (CO_2) as the shielding gas. Because of high spatter in CO2, in the present analysis 80%Ar-20% CO_2 mixture has been taken for shielding gas. GMAW process is used for the study. Figure 1 gives the GMAW experimental setup used for welding HSLA steel. The test pieces were preheated to 100ºC and 150ºC prior to welding.

Fig 1. Gas Metal Arc Welding Setup

ISSN 2321-807X
Volume 13 Number3
Journal of Advances in Chemistry

Y-GROOVE TEKKEN TEST

Y-groove Tekken test is used to study the cold cracking susceptibility of the welded metal. Y-groove Tekken test specimens are prepared as shown in figure 2. The Tekken test was carried out as described in the standard DIN EN ISO 17642-2 [11,12].

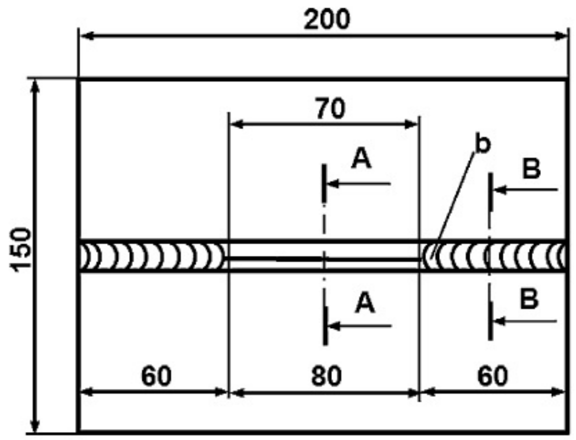

Fig 2: Dimesions of test specimen (All dimensions are in mm)

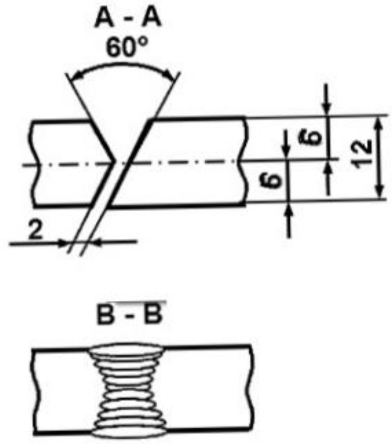

Fig 3: Cross section of test weld and auxiliary weld

Figure 3 gives the cross section of the test and auxiliary welds. The test specimens were arranged for the required gap of 2 mm between them. The auxiliary welding was made for 60mm in two ends. Then the test welding was carried out in single pass. After welding, the material was kept for normal cooling. The welded material was allowed for 48 hours cooling and the material was cut into the five sections for analyzing the cold cracks. Figure 4 gives the five testpieces cut from the test weld. The welding trials were conducted using the standard procedures. The levels of parameters were determined based on preliminary tests. The welding parameters for the test weld were 25Volts, 10mm/minute wire feed rate and 200inch/ minute table speed.

Fig. 4. Test pieces cut from the test weld

Figure 5 shows the cross section of the test material after welding. The material was cut into five pieces in the test weld region and analyzed for the micro structural constituents and cold cracks.

Fig. 5. Cut section of the Test weld

RESULTS AND DISCUSSIONS

The welded specimen was allowed to be kept for about 72 hours and cut at different locations to study the microstructure and for cold cracking. Figure 6 gives the microstructure of the base metal HSLA 950A at 400X magnification.

Fig 6: Microstructure of HSLA 950A base

Figure 7 gives the microstructure of the weld metal at 1000X. The weld metal microstructure reveals the presence of bainite structure consisting of upper and lower bainite. The microstructure gives the lathe martensite and some traces of acicular ferrite. The acicular ferrite is the most important constituent of weld metal which influence the cold cracking resistance[17-19]**.**

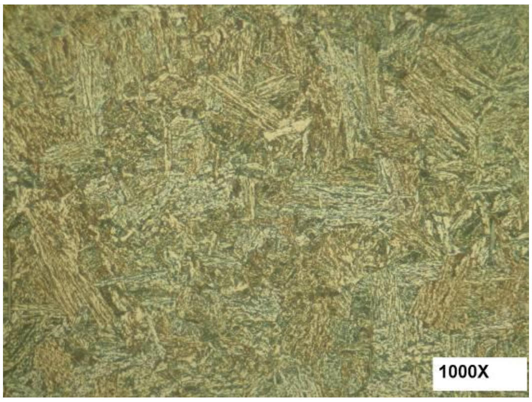

Fig 7: Microsturucture of weldmetal at 1000X

Table 5 gives the metallographic results of Y groove tekken test. In the metallographic analysis of the welded sample the crack found in both weld metal and heat affected zone.

Table 5. Results of Y Groove Tekken test

S.No.	Preheating Temperature	Microstructure Constituent	Metallographic Finding
1	100ºC	Bainite lath martensite	CC WM
2	150ºC	Acicular ferrite, polygonal ferrite	CC HAZ

Further analysis proceeds into the type of crack formed in welding. Two different cracks were found in the analysis. The first crack found in the heat affected zone propogated to weld metal. This type of crack is termed as Chevron type of crack. Figure 8a shows the grey scale image of the test weld cross section showing the crack at the weld metal at preheating temperature of 100ºC. The crack initiated from the heat affected zone tends to grow into weld metal and finally tend to fail the weld metal. The crack propagation was reduced due to the presence of acicular ferrite microstructure in weld metal.

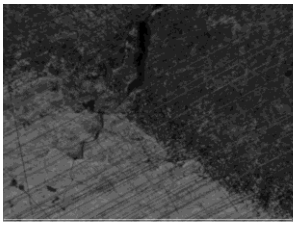

Fig: 8 Crack found in weld metal

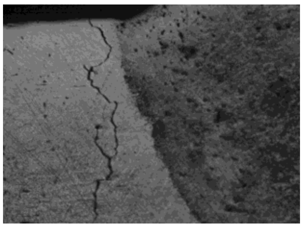

Fig: 9 Crack in Heat affected zone of the weld

Another type of crack was found in the heat affected zone of the weld metal. In the same manner crack formation in heat affected zone also affected the weld metal strength. Figure 9 shows the grey scale image of the crack formed in heat affected zone at preheating temperature of 150ºC. Because of higher preheating temperatures, the weld metal has more acicular ferrite compared with the sample preheated to 100ºC. Hence, preheating of the base metal prior to welding is essential in improving the cold cracking resistance and thereby reduces the cooling rate[21-24]. Analysis of the cold crack susceptibility with short range of temperature is inconclusive and hence studies with higher range of temperature is necessary to conclude the effect of preheating temperature.

CONCLUSION

The performed experimental investigations on weldments of HSLA steel SAE grade 950A by Tekken test clearly shows that within the covered range of welding conditions cold cracking may occur in the weld metal. Cracks are found in the heat affected zone and in weld metal. The crack is surface crack and perpendicular to the residual solidification stress. From the microstructure analysis, it is observed that the acicular ferrite formed in the weld metal has greater cold cracking resistance[13-14]. It is viewed in the microstructure that those weld metals having good resistance to the cold cracking posses has acicular ferrite microstructure. The preheating temperature is also having more influence on the microstructure that can be varied to have a better weld metal with good mechanical properties. The higher the preheating temperature, higher is the resistance to cold cracking[20]. The weld metal is not susceptible to hydrogen induced cracking, if the metal is preheated to 150ºC. It has been analysed that the preheating temperature is to be increased so as to increase the cold cracking resistance. Conclsions can be drawn that wide range of preheating temperature are to be selected and varied for effective applications of research findings in future.

REFERENCES

1. Prasad Keshav, and D. K. Dwivedi. "Some investigations on microstructure and mechanical properties of submerged arc welded HSLA steel joints." The international journal of advanced manufacturing technology 36.5-6 (2008): 475-483
2. Malina, Jadranka, I. Samardzic, and Vladimir Gliha. "Susceptibility to hydrogen-induced cracking of weld beads on high-strength structural steel." Materials Science 41.2 (2005): 253-258.
3. Kannengiesser, Thomas, and Thomas Boellinghaus. "Cold cracking tests—an overview of present technologies and applications." Welding in the World 57.1 (2013): 3-37.
4. Magudeeswaran, G., V. Balasubramanian, and G. Madhusudhan Reddy. "Hydrogen induced cold cracking studies on armour grade high strength, quenched and tempered steel weldments." International journal of hydrogen energy 33.7 (2008): 1897-1908
5. Węglowski, M. St, and M. Zeman. "Prevention of cold cracking in ultra-high strength steel Weldox 1300." Archives of Civil and Mechanical engineering 14.3 (2014): 417-424.
6. Banerjee, Kumkum. "Hydrogen-Induced Cold Cracking in High-Frequency Induction Welded Steel Tubes." Metallurgical and Materials Transactions A 47.4 (2016): 1677-1685
7. Brown, I. H. "The role of microsegregation in centreline cold cracking of high strength low alloy steel weldments." Scripta materialia 54.3 (2006): 489-492.
8. Savage, W. F., E. F. Nippes, and Y. Tokunaga. "Hydrogen induced cracking in HY-130 steel weldments." Welding journal 57.4 (1978): 118-126.
9. Kurji, Rahim, and Nicola Coniglio. "Towards the establishment of weldability test standards for hydrogen-assisted cold cracking." The International Journal of Advanced Manufacturing Technology 77.9-12 (2015): 1581-1597.
10. Alexandrov, B., Theis, M. Streitenberger, H. Herold, I. Martinek, Cold cracking in weldments of steel S 690 QT, Welding in the World, Vol. 49, no 5/6, 2005, 64-73.
11. Sun, Y. B., and J. E. Indacochea. "Hydrogen induced cracking in cold worked AISI 4140 steel welds." Journal of materials science 23.7 (1988): 2339-2347.
12. Magudeeswaran, G., V. Balasubramanian, and G. Madhusudhan Reddy. "Effect of welding consumables on fatigue performance of shielded metal arc welded high strength, Q&T steel joints." Journal of materials engineering and performance 18.1 (2009): 49-56.
13. Seo, Jun Seok, Hee Jin Kim, and Hoi Soo Ryoo. "Effect of grain boundary ferrite on susceptibility to cold cracking in high-strength weld metal." Metals and Materials International 14.4 (2008): 515-522.
14. Kim, Sanghoon, Jun Seok Seo, and Changhee Lee. "Cold cracking susceptibility of boron added high-strength bainitic steels." Metals and Materials International 18.6 (2012): 1029-1036.
15. Pitrun, M., and D. Nolan. "Susceptibility of low strength rutile flux-cored weld metal to hydrogen assisted cold cracking." Welding in the World 50.5-6 (2006): 24-37.
16. Stevenson, M. E., et al. "Metallurgical failure analysis of cold cracking in a structural steel weldment: Revisiting a classic failure mechanism." Practical Failure Analysis 2.4 (2002): 55-60.
17. Yi, Hui-Jun, et al. "Effect of microstructure and chemical composition on cold crack susceptibility of high-strength weld metal." Journal of mechanical science and technology 25.9 (2011): 2185-2193.
18. Tasak, Edmund, Aneta Ziewiec, and Janusz Adamiec. "The role of hydrogen in weld cracking processes–a new look at the problem." Welding International 25.06 (2011): 409-414.
19. Nevasmaa, P. "Prevention of weld metal hydrogen cracking in high-strength multipass welds." Welding in the World 48.5-6 (2004): 2-18.

20. Nevasmaa, P., and A. Laukkanen. "Assessment of hydrogen cracking risk in multipass weld metal of 2.25 Cr-1Mo-0.25 V-TiB (T24) boiler steel." Welding in the World 49.7-8 (2005): 45-58.

21. Pitrun, M., D. Nolan, and D. Dunne. "Diffusible hydrogen content in rutile flux-cored arc welds as a function of the welding parameters." Welding in the World 48.1-2 (2004): 2-13.

22. Elboujdaini, M., and R. W. Revie. "Metallurgical factors in stress corrosion cracking (SCC) and hydrogen-induced cracking (HIC)." Journal of solid state electrochemistry 13.7 (2009): 1091-1099.

23. Thompson, Anthony W., and I. M. Bernstein. "The role of metallurgical variables in hydrogen-assisted environmental fracture." Advances in corrosion science and technology. Springer US, 1980. 53-175.

24. Manimozhi, S., S. Suresh, and V. Muthupandi. "HAZ hydrogen cracking of 9Cr-0.5 Mo-1.7 W steels." The International Journal of Advanced Manufacturing Technology 51.1-4 (2010): 217-223.

.